REMARKS

Prior to this Amendment, claims 1-4 and 6-10 were pending in the Application. In this Amendment, claim 1 has been amended, claims 11-16 have been added, and no claims have been cancelled. Thus, claims 1-4 and 6-16 are pending in the application.

Claim Amendment and New Claims

Claim 1 has been amended to clarify the claim. Applicants submit that the Amendment to claim 1 does not narrow the claim and is not being made for substantial reasons related to patentability. Furthermore, the Amendment to claim 1 is not being made in view of any prior art and does not surrender any subject matter.

New claims 11-16 have been added. Applicants submit that claims 11-16 are supported by the application as originally filed and thus, do not include new matter. Furthermore, Applicants submit claims 11-16 are allowable.

Drawings

In paragraph 2 of the Office Action, the drawings where objected to under 37 C.F.R. § 1.83(a). The objection to the drawings is directed to Fig. 2 and is a continuation of a drawing objection in the previous Office Action dated May 10, 2002.

Referring to the discussion with the Examiner, Applicants submit a new Fig. 2 showing a flexible printed circuit board 10 according to the present invention. Fig. 2 includes section lines which are different from the section lines shown in Fig. 1. Accordingly, an Example of Applicants' flexible printed circuit board is shown in Fig. 2, whereas a conventional circuit board is shown in Fig. 1. Applicants submit that Fig. 2 does not include new matter and is supported by the application as originally filed.

Fig. 2 also includes new reference numerals 11, 12, 13, 14 and 15. Also, original Fig. 2 has been amended to be new Fig. 3. If new Fig. 2 overcomes the drawing objection and the objection is withdrawn, the specification will be amended to be consistent with Figs. 1-3.

Claim Rejections – 35 U.S.C. § 103

In paragraph 4 of the Office Action, claims 1-4, and 6-10 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Gurrie et al. (US 5,296,651) in view of Noda et al. (US 4,913,955). Applicants respectfully disagree.

In an embodiment, the present invention provides a flexible printed circuit board comprising a base film, a base film side adhesive layer provided on the base film, a metal foil layer on which a pattern circuit is formed provided on the base film, a cover layer side adhesive layer, and a cover layer film, layered in that order from the bottom of the flexible printed circuit board. At least one of the base film side adhesive layer and the cover layer side adhesive layer has a higher glass transition temperature than the operating temperature of the flexible printed circuit board. Further, a reciprocation number N indicating a bending life of the flexible printed circuit board is at least ten million times at 60°C.

The present invention provides an advantage of remarkably improving the flex life (high repeated flexing) of flexible printed circuit boards. Prior flexible printed circuit boards exhibited significantly lower ability to repeatedly flex.

Applicants provide an explanation of the relationship between a storage modulus and a glass transition temperature (Tg) of an adhesive layer in a flexible printed circuit (FPC) board as follows. Because Applicants' FPC board invention has a high glass transition temperature (Tg), the FPC board has an improved storage modulus at the operating temperature of the FPC board. The improved storage modulus provides Applicants' FPC board with a remarkably high flex life of repeated bending. Applicants believe the following explanation will aid in the understanding of the remarkably increased flex life of FPC boards provided by the present invention.

Applicants' FPC board having an adhesive layer with a high Tg and high fatigue resistance is used for repeatedly bending of a few million or more times in a bending strain state. Applicants' FPC board can function because the shape of a circuit metal is maintained so as not to break, even if the FPC board undergoes severe bending fatigue. Existing FPC boards having metal circuits tend to fail due to excessive bending fatigue. Bending fatigue is a state in which fine defects in the metal circuit repeatedly occur and decay according to distortion of the metal. The metal is repeatedly recrystallized according to the occurrence and decay of the fine defects. Subsequently, the crystal structure of the metal is gradually changed according to the recrystallization. The metal is normally broken (failure) due to repeated bending and fatigue.

The inventors of the present invention have addressed the bending fatigue problem by providing an FPC board having a bending life (fatigue life) improved by applying an adhesive which is harder than a normal adhesive used in FPC boards around the circuit metal so as to maintain the shape of the metal circuit by improving the circuit metal bending fatigue resistance.

When the operational temperature is above a glass transition temperature (Tg) of an adhesive layer, the adhesive is softened. In the FPC board according to the present invention, an adhesive layer having a high Tg is used so that the adhesive does not soften at high temperature.

A storage modulus E of adhesives of about 0.1 GPa improves bending life. Epoxy based adhesives, such as in FPC boards, have a storage modulus E of about 0.1 GPa at room temperature. However, the storage modulus of epoxy based adhesives is reduced to 0.01 to 0.001 GPa when operational temperature is above the glass transition temperature of the epoxy based adhesives, and the FPC board is subject to bending fatigue. Conversely, in Applicants' invention, as claimed in claim 1, "at least one of the base film side adhesive layer and the cover layer side adhesive layer has a higher glass transition temperature than an operating temperature of the flexible printed circuit board" provides an FPC board with a high storage modulus and remarkably high resistance to bending fatigue.

As long as the adhesive has a storage modulus of 0.1 GPa or more, even if the operational temperature is above Tg, bending life can be improved. On the other hand, when the adhesive has a storage modulus of less than 0.1 GPa, even if the operational temperature is below Tg, bending life cannot be improved. Accordingly, Applicants' invention having a high Tg provides an improved FPC board having a high storage modulus which provides a remarkably high bending flex life. In other words, an important aspect to the improved bending life of Applicants' invention is the storage modulus of adhesives due to the high Tg.

The Response to Office Action submitted March 19, 2003 responded to the claim rejections in the Office Action. Applicants reiterate the previous comments distinguishing the present claimed invention from Gurrie et al. and Noda et al.

The Office Action asserts that Gurrie et al. discloses a flexible printed circuit board (10) comprising: a base film (24); a base film side adhesive layer (22) provided on the base film (24); a metal coil (probably a typographical error for "foil") layer (12) on which a pattern circuit is formed, provided on the base film side adhesive layer (22); and a cover layer side adhesive layer (20) provided on the metal foil layer (12).

The Office Action acknowledges, however, that Gurrie et al. does not teach a material made of an epoxy resin adhesive which forms the base film side adhesive layer and cover layer side adhesive layer and has a higher glass transition temperature (greater than 60 to 80 degrees Celsius) than an operating temperature of the flexible circuit board.

Gurrie et al. pertains to a circuit having objects in which flexibility and flex life are not reduced and cross-talk is eliminated by electrically shielding conductor traces. The Gurrie et al. flexible circuit includes (1) plural conductor traces positioned along the neutral axis, and (2) a thin film metallic planar conductor (which corresponds to ground plane 18 being a sputtered copper film) formed on at least one of the dielectric layers on the surface facing the conductor traces.

As shown in Fig. 2a of Gurrie et al., the flexible circuit comprises dielectric substrates 16 and 24, adhesive layers 20 and 22 bonding conductor traces 12 between dielectric substrates 16 and 24, conductor traces 12 centered along neutral axis 14 of flex circuit 10, and ground plane 18 formed on at least one of the dielectric layers.

On the other hand, an object of the present invention is to stably obtain a flexible printed circuit (FPC) having excellent flexural fatigue endurance (bending life) even if the FPC is used in equipment such as a hard disk drive (HDD) in which change of the operating (environmental) temperature is anticipated to vary from room temperature up to about 80°C. For example, when the FPC is used in equipment such as an HDD, the FPC is flexibly bent according to movement of a movable part, such as a read/write head, and the reciprocation number N indicating the bending life of the FPC (the flexural fatigue endurance) is from 1×10^6 times (cycles) to 1×10^7 times (cycles) or even up to 1×10^9 times (cycles). The FPC can have superior flexural fatigue endurance (bending life) indicated by a remarkably high reciprocation number N.

However, Gurrie et al. does not disclose nor suggest that at least one of the base film side adhesive layer and the cover layer side adhesive layer has a higher glass transition temperature than the operating temperature of the flexible printed circuit board. Gurrie et al. also does not disclose nor suggest a reciprocation number N indicated a bending life of the flexible printed circuit board is at least ten million times at 60°C.

Since the flexible circuit of Gurrie et al. has a copper film provided at the inner surface of the dielectric layer, for example, the Gurrie et al. flexible circuit cannot endure being repeatedly bent according to movement of a movable part such as a read/write head. That is, if the same

test for the bending life of the present invention is applied to the flexible circuit of Gurrie et al., the Gurrie et al. flexible circuit will not have the reciprocation number N indicating the bending life of 1×10^6 times (cycles) to 1×10^7 times (cycles) or even up to 1×10^9 times (cycles). Gurrie's "flex life" is quite different from the present invention's "bending life".

Therefore, the present invention completely differs from the invention of Gurrie et al. in objects, structure, and effects.

As to Noda et al., the Office Action asserts that Noda et al. teaches a flexible circuit board (1) comprising a center adhesive layer (5) made by an epoxy resin adhesive that provides a higher glass transition temperature (about 130 degrees Celsius) than an operation temperature.

Noda et al. relates to a laminate or a bendable laminate adapted to have low flexion, and is used for a printed circuit. In Fig. 1 of Noda et al., the center adhesive layer 5 is composed of glass fiber woven cloth and is permeated with epoxy resin to harden the circuit in order for it to be difficult to deform (bend) when external force (stress) is applied.

On the other hand, the present invention relates to an FPC. An object of the present invention is to stably obtain an FPC having excellent flexural fatigue endurance (bending life) even if the FPC is used in equipment such as a hard disk drive (HDD) unit in which change of the operating (environmental) temperature is anticipated to vary from room temperature up to about 80°C. For example, when the FPC is used in equipment such as an HDD unit, the FPC is flexibly bent according to movement of a movable part, such as a read/write head, and the reciprocation number N indicating the bending life of the FPC (the flexural fatigue endurance) is from 1×10^6 times (cycles) to 1×10^7 times (cycles) or even up to 1×10^9 times (cycles). The FPC can have superior flexural fatigue endurance (bending life) indicated by the remarkably high reciprocation number N. In other words, when the bending part being in bending state undergoes a certain strain, the bending life can be prolonged according to the above structure of the present invention.

Noda et al., however, does not disclose nor suggest the above object of the present invention.

If the same bending life test is applied to the laminate of Noda et al., it is difficult to uniformly and repeatedly bend the form retentive substrate, which is formed so as to be prevented from bending. In addition, in the bending state, the form retentive substrate cannot

endure the reciprocation number N indicating a bending life of 1×10^6 times (cycles) to 1×10^7 (times) cycles or even up to 1×10^9 times (cycles).

Therefore, the present invention completely differs from the invention of Noda et al. in objects, structure and effects.

The Noda et al. substrate also has the following characteristics:

(1) Noda et al. purports to address a problem in the prior art of flexible circuit boards not holding a bent configuration (being too flexible) by providing a bendable hard printed circuit board in order to remove wiring such as a flexible circuit board for connecting hard printed circuit boards, because it is necessary to use the wiring for connecting a plurality of hard printed circuit boards in a conventional hard printed circuit board;

(2) Accordingly, it is necessary to maintain the bendable hard printed circuit board in the bent condition. The bending characteristic was appreciated by winding the laminate around a cylindrical rod 7 and measuring a radius R (mm) of the bent condition of the laminate after the bending stress was relieved (Noda et al., column 4, lines 41-47). (This measuring method completely differs from the measuring method of the bending fatigue of the present invention.) Furthermore, size stability and the like were also appreciated;

(3) The glass fiber woven cloth is provided on both faces of the center base layer 5 in order to increase the stability of the bent shape, i.e., <u>reduce</u> repetitive flexing; and

(4) The composite having a high glass transference temperature is used in order to hold the bending characteristic when it is subject to high temperature treatment such as automatic soldering process (Noda et al., column 2, lines 63-68).

The above characteristics differ significantly from characteristics of the present invention in objects, structure, and effects.

Furthermore, Gurrie et al. and Noda et al. do not disclose the characteristic of the present invention in which at least one of the base film side adhesive layer and the cover layer side adhesive layer has a higher glass transition temperature than an operating temperature of the FPC, and a reciprocation number N indicating a bending life of the flexible printed circuit board is at least ten million times at 60°C. Therefore, the present invention completely differs from the devices of Gurrie et al. and Noda et al.

The Office Action asserts that it would have been obvious to one having ordinary skill in the art at the time the invention was made to use an epoxy resin adhesive that provides a higher

glass transition temperature than an operation temperature as taught by Noda et al. to employ the flexible circuit board of Gurrie et al. in order to provide a flexion of laminate of the flexible circuit board at high temperature, and also provide a flex life of the flexible circuit board being the number of times the circuit can be flexed before failing.

The Office Action further asserts that Gurrie et al. and Noda et al. disclose the bending life of the flexible circuit board which in a range to provide a long life for the flexible circuit board having the epoxy resin including high glass temperature about 130 degrees Celsius. Although, Gurrie et al. and Noda et al. do not explicitly state the number of flexures, since Noda et al. is using the same material.

However, Noda et al. teaches away from increasing flexibility by seeking to reduce flexion. Further, Noda et al. does not disclose that at least one of the base film side adhesive layer and the cover layer side adhesive layer has a higher glass transition temperature than an operating temperature of the FPC.

In Noda et al., an epoxy resin adhesive having a high glass transition temperature is used to hold the bending characteristic (maintain the flexible circuit board in the bent condition) when it is subject to high temperature treatment such as automatic soldering process. This does not provide a flexion of laminate of the flexible circuit board at high temperature.

On the other hand, the present invention provides not only using an epoxy resin, but also at least one of the base film side adhesive layer and the cover layer side adhesive layer having a higher glass transition temperature than an operating temperature of the FPC. As a result, an FPC having excellent flexural fatigue endurance (bending life) is stably obtained even if the FPC is used in equipment such as a hard disk drive (HDD) in which change of the operating (environmental) temperature is anticipated to vary from room temperature up to about 80°C.

Furthermore, the Office Action seems to equate the "number of flexures," relative to Gurrie et al. and Noda et al. to Applicants' "reciprocation number." However, the "number of flexures" is not the same as the "reciprocation number" of the present invention. The former indicates the number of bending of the flexible circuit board, and the latter indicates the number of horizontal reciprocation of the flexible printed circuit board according to the movement of a movable part with holding the bending state (bent condition). These tests mean that objects, structures, and effects of the present invention differs from those of Gurrie et al. and Noda et al.

Furthermore, since Gurrie et al. and Noda et al. have different objects, structures, and effects, it is not obvious to combine Gurrie et al. and Noda et al. because the glass fiber woven cloth permeated by epoxy resin to be used in the form retentive substrate of Noda et al. introduced into the adhesive layer of the flexible circuit of Gurrie et al. would be contrary to Gurrie et al. by stiffening the Gurrie et al. laminate. Even if Gurrie et al. and Noda et al. are combined, the combination would include the glass fiber woven cloth which is not used in the present invention. Further, the characteristic of the present invention to improve bending life of bending parts by the difference between the glass transition temperature of the adhesive layer and the operating temperature of the FPC would not be achieved by the combination.

The bending life of the present invention is not evaluated based on a few bending cycles, but is evaluated based on the number of bending cycles up to breakage of the FPC, in particular, the remarkably high number is from 1×10^6 times (cycles) to 1×10^7 times (cycles) or even up to 1×10^9 times (cycles).

This is neither disclosed nor suggested in either Gurrie et al. or Noda et al.

Therefore, it would not have been obvious to one having ordinary skill in the art at the time of the invention was made to have a bending life of one million to ten million times to provide the expected longevity of the flexible circuit board.

Thus, Applicants respectfully submit that the §103 rejection has been overcome.

Applicants further submit that new claims 11-16 are allowable. Claims 11-16 further define the at least one adhesive layer. Neither Gurrie et al. or Noda et al. disclose or suggest the features of claims 11-16.

CONCLUSION

For the foregoing reasons, Applicants submit that the patent application is in condition for allowance and request a Notice of Allowance be issued.

Respectfully submitted,

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